Disorder and glassy behavior at low temperatures

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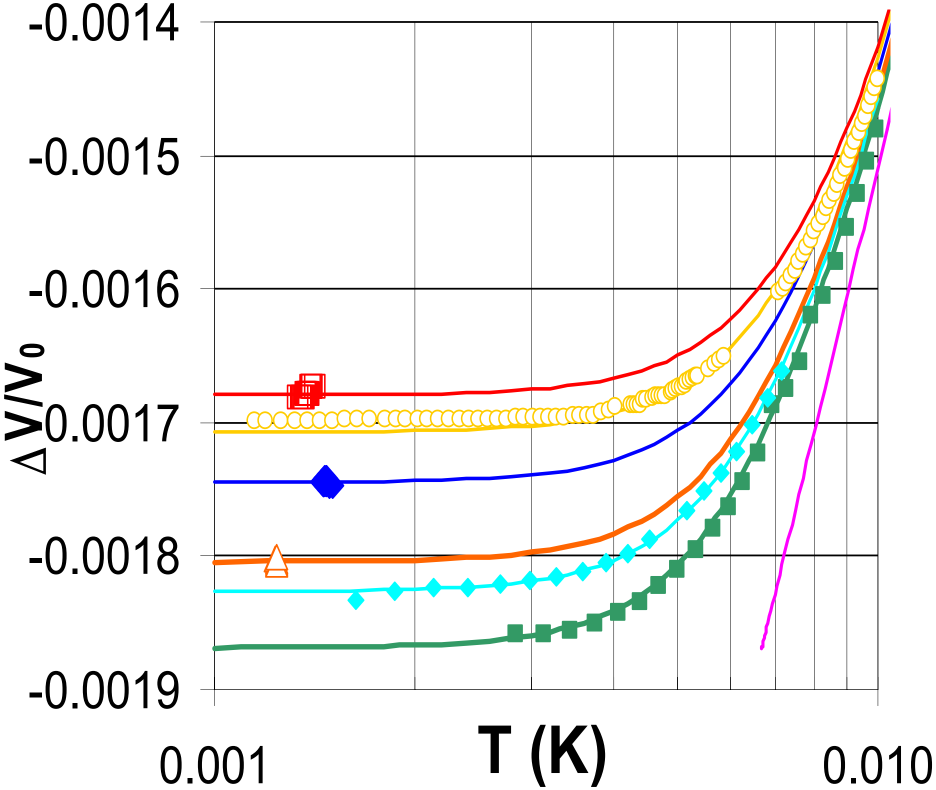

Data from top to bottom 552h, 648 h, 816h, 1152h, 1725h and 1800h after cooling to 4K. The lilac line at right is the ideal long term behavior.

J. Low Temp Phys (submitted).

Glassy, disordered material is the most common state of matter. What happens when the disordered state is taken to very low temperatures?

At these low temperatures, the atoms nearly cease to move in the conventional sense. Instead they "tunnel" quantum mechanically from one state to another. This tunneling is accompanied by heat release as the atoms move from a high energy configuration to a lower energy state. The heat release elevates the temperature of the sample, but the rate of heat release slows down with time, showing up as a progressively lower velocity as the sample approaches the ideal (lilac) line in the figure at left.

We measured the sound velocity in epoxy 1266 as a function of temperature. The low temperature (<10mK) behavior shows a strong time dependence.

No such time dependence has been measured out to this long a time previously.

Data shown were acquired (from top to bottom) 552h, 648 h, 816h, 1152h, 1725h and 1800h after the transfer of liquid helium. The lilac line is the expected dependence based on the tunneling model.

The internal heat release, presumably from the reorientation of the tunneling entities (atoms or groups of atoms), is still 10 pw/g after nearly 2000 hours.

This has a profound impact on the design of all sorts of low temperature apparatus, in terms of the limitations of the lowest achievable temperatures. Epoxy 1266 is one of the mainstay materials used in building all sorts of low temperature apparatus. Taken a step further, all glasses eg vycor and aerogel, will release heat into helium in potentially significant quantities at low temperatures.

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- Education

A post doc, Evgueni Nazaretski, and a grad student (Svetoslav Dimov) led this work.

Evgueni is now a staff member at Los Alamos.

Svetoslav is continuing this work at Cornell.

Daniel Finkelstein-Shapiro a freshman Physics major at Cornell (and Presidential Research Scholar) is participating in similar work this summer as is

Andrew Fefferman, a first year Grad Student at Cornell.

Pohl and Parpia are Professors at Cornell.

- Societal Impact

The ability to examine disorder at all time scales (from the fast processes that can be probed optically) to ultra slow processes that show up in thermodynamics allows us to examine models for dynamics in disordered systems.

Aging of materials is a quintessential problem and glassy systems are no exceptions to this.